RELIABILITY

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Introduction to Reliability Engineering

- No one disputes the need for engineered products to be reliable.
- The average consumer is aware of the problem of less than perfect reliability in domestic products such as TV sets and automobiles.
- Organizations such as airlines, the military and public utilities are aware of the costs of unreliability.
- Manufacturers often suffer high costs of failure under warranty.

Introduction to Reliability Engineering

- Argument and misunderstanding begin when we try to quantify reliability values, or try to assign financial or other cost or benefit values to levels of reliability.
- The simplest, purely producer-oriented or inspectors' view of quality is that in which a product is assessed against a specification or set of attributes, and when passed is delivered to the customer.
- The customer, having accepted the product, accepts that it might fail at some future time.

Introduction to Reliability Engineering

- This simple approach is often coupled with a warranty, or the customer may have some protection in law, so that he may claim for failures occurring within a stated or reasonable time.
- However, this approach provides no measure of quality over a period of time, particularly outside a warranty period.
- Even within warranty period, customer usually has no grounds for further action if product fails once, or several times, provided that manufacturer repairs the product as promised each time.

Introduction to Reliability Engineering

- If it fails often, the manufacturer will suffer high warranty costs, and the customers will suffer inconvenience.
- Outside the warranty period, only the customer suffers.
- In any case, the manufacturer will also probably incur a loss of reputation, possibly affecting future business.
- We therefore come to the need for a time-based concept of quality.

Introduction to Reliability Engineering

- The inspectors' concept is not time dependent. The product either passes a given test or it fails.
- On the other hand, reliability is usually concerned with failures in the time domain.
- This distinction marks the difference between traditional quality control and reliability engineering.
- Whether failures occur or not, and their times to occurrence, can seldom be forecast accurately.
- Reliability is therefore an aspect of engineering uncertainty.

Introduction to Reliability Engineering

- Whether an item will work for a particular period is a question which can be answered as a probability.
- This results in the usual engineering definition of reliability as:

"The probability that an item will perform a required function without failure under stated conditions for a stated period of time."

- Reliability can also be expressed as the number of failures over a period.

Introduction to Reliability Engineering

- The objectives of reliability engineering, in the order of priority, are:

a) To apply engineering knowledge and specialist techniques to prevent or to reduce the likelihood or frequency of failures.

b) To identify and correct the causes of failures that do occur, despite the efforts to prevent them.

c) To determine ways of coping with failures that do occur, if their causes have not been corrected.

d) To apply methods for estimating the likely reliability of new designs, and for analysing reliability data

Reliability Engineering

- The reason for the priority emphasis is that it is by far the most effective way of working, in terms of minimizing costs and generating reliable products.
- The primary skills that are required, therefore, are the ability to understand and anticipate the possible causes of failures, and knowledge of how to prevent them.
- It is also necessary to have knowledge of the methods that can be used for analysing designs and data.

Reliability Engineering

- The primary skills are nothing more than good engineering knowledge and experience, so reliability engineering is first and foremost the application of good engineering, in the widest sense, during design, development, manufacture and service.
- Mathematical and statistical methods can be used for quantifying reliability (prediction, measurement) and for analysing reliability data.

Reliability Engineering

- The basic methods are described to provide an introduction for some of the applications described subsequently.
- However, because of the high levels of uncertainty involved these can seldom be applied with the kind of precision and credibility that engineers are accustomed to when dealing with most other problems.
- In practice the uncertainty is often in orders of magnitude. Therefore the role of mathematical and statistical methods in reliability is limited.

Reliability Engineering

- Reliability (and very often also safety) is such a critical parameter of most modern engineering products, and since failures are generated primarily by the people involved (designers, test engineers, manufacturing, suppliers, maintainers, users).
- It can be maximized only by an integrated effort that encompasses training, teamwork, discipline, and application of the most appropriate methods.

Reliability Engineering

- Reliability engineering "specialists" cannot make "integrated effort" to happen.
- They can provide support, training and tools, but only managers can organize, motivate, lead and provide the resources.
- Reliability engineering is, ultimately, effective management of engineering.

Why Reliability Engineering is Important

- Engineering education is traditionally concerned with teaching how manufactured products work.

- But the ways in which products fail, the effects of failure and aspects of design, manufacture, maintenance and use which affect the likelihood of failure are not usually taught, mainly because it is necessary to understand how a product works before considering ways in which it might fail.

Why Reliability Engineering is Important

- For many products the tendency to approach the failed state is analogous to entropy.
- The engineer's tasks are to design and maintain the product so that the failed state is deferred.
- In these tasks he faces problems inherent in the variability of engineering materials, processes and applications.
- Engineering education is basically deterministic, and does not usually pay sufficient attention to variability.

Why Reliability Engineering is Important

- Yet variability and chance play a vital role in determining the reliability of most products.
- Basic parameters like mass, dimensions, friction coefficients, strengths and stresses are never absolute, but are in practice subject to variability due to process and materials variations, human factors and applications.
- Understanding the laws of chance and the causes and effects of variability is therefore necessary for the creation of reliable products and for the solution of problems of unreliability.

Why Do Engineering Products Fail?

- There are many reasons why a product might fail. Knowing the potential causes of failures is fundamental to preventing them.
- It is rarely practicable to anticipate all of the causes, so it is also necessary to take account of the uncertainty involved.
- Reliability engineering effort, during design, development and in manufacture and service should address all of the anticipated and possibly unanticipated causes of failure, to ensure their occurrence is prevented or minimized.

Why Do Engineering Products Fail?

- The main reasons why failures occur are:

1. The design might be inherently incapable.
2. The item might be overstressed in some way.
3. Failures might be caused by variation in strength.
4. Failures can be caused by wearout.
5. Failures can be caused by time-dependent mechanisms such as creep.
6. Failures can be caused by sneaks.
7. Failures can be caused by errors, like incorrect specifications, designs or software coding

Probabilistic Reliability

- The concept of reliability as a probability means that any attempt to quantify it must involve the use of statistical methods.
- An understanding of statistics as applicable to reliability engineering is therefore a necessary basis for progress, except for the special cases when reliability is perfect (we know the item will never fail) or it is zero (the item will never work).
- In engineering we try to ensure 100 % reliability, but our experience tells us that we do not always succeed.

Probabilistic Reliability

- Therefore reliability statistics are usually concerned with probability values which are very high (or very low)
- Probability that a failure does occur is usually given by (1 – reliability).
- Quantifying such numbers brings increased uncertainty, since we need more information.
- Other sources of uncertainty are introduced because reliability is often about people who make and use the product, and because of varying environments in which products operate.

Probabilistic Reliability

- We can specify a reliability
  - as the mean number of failures in a given time (failure rate),
  - or as the mean time between failures (MTBF) for items which are repaired and returned to use,
  - or as the mean time to failure (MTTF) for items which are not repaired,
  - or as the proportion of the total population of items failing during the mission life.

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Probabilistic Reliability

- The application and interpretation of statistics to deal with the effects of variability on reliability are less straightforward than in measurement of human variations.
- In applications focus is mainly on the behaviour of the larger part of the population while variation is not very large.
- In reliability main concerned is in the behaviour of the extreme tails of distributions

Probabilistic Reliability

- The statistician working in reliability engineering needs to be aware of the fact that variation is often a function of time such as operating cycles, maintenance periods etc.
- Reliability data from any past situation cannot be used to make credible forecasts of the future behaviour, without taking into account non-statistical factors such as design changes, maintainer training, or service problems

Repairable and Non-Repairable Items

- It is important to distinguish between repairable and non-repairable items when predicting or measuring reliability
- For a non-repairable item such as a light bulb, a transistor, a rocket motor or an unmanned spacecraft, reliability is the **survival probability** over the item’s expected life, or for a period during its life, **when only one failure can occur**.
- During the item’s life the instantaneous probability of the first and only failure is called the **hazard rate.**

Repairable and Non-Repairable Items

- Life values such as the mean life or mean time to failure (MTTF), or the expected life by which a certain percentage might have failed (say 10 %.) (percentile life), are other reliability characteristics that can be used.
- Note that non-repairable items may be individual parts (light bulbs, transistors, fasteners) or systems comprised of many parts (spacecraft, microprocessors).

Repairable and Non-Repairable Items

- For items which are repaired when they fail, reliability is the probability that failure will not occur in the period of interest, when more than one failure can occur.
- It can also be expressed as the rate of occurrence of failures (ROCOF), which is sometimes referred as the failure rate (usually denoted as λ).
- However, the term failure rate has wider meaning and is often applied to both repairable and non-repairable systems

Repairable and Non-Repairable Items

- For non-repairable parts failure rate is expressing the number of failures per unit time, as applied to one unit in the population, when one or more failures can occur in a time continuum.
- It is also sometimes used as an averaged value or practical metric for the hazard rate.
- Repairable system reliability can also be characterized by the mean time between failures (MTBF), but only under the particular condition of a constant failure rate.

Repairable and Non-Repairable Items

- It is often assumed that failures do occur at a constant rate, in which case

$$Failure\ rate(\lambda) = \frac{1}{(MTBF)}$$

- However, this is only a special case.
- It is valuable because it is often true and because it is easy to understand.
- Sometimes an item may be considered as both

Repairable and Non-Repairable Items

- For example, missile is repairable system when it is in store and subjected to scheduled tests, but it becomes non-repairable when it is launched.
- Reliability analysis of such systems must take account of these separate states.
- Repairability might also be determined by other considerations. For example, whether electronic circuit board is treated as a repairable item or not will depend upon the cost of repair.
- An engine or a vehicle might be treated as repairable only up to a certain age.

Repairable and Non-Repairable Items

- Another concerned in reliability is the availability of repairable items, since repair takes time.
- Availability is affected by the rate of occurrence of failures (failure rate) and by maintenance time.
- Maintenance can be corrective (i.e. repair) or preventive (to reduce the likelihood of failure, e.g. lubrication).
- We therefore need to understand the relationship between reliability and maintenance, and how both reliability and maintainability can affect availability.

DURABILITY

- Durability is a particular aspect of reliability, related to the ability of an item to withstand the effects of time (or of distance travelled, operating cycles, etc.) dependent mechanisms such as fatigue, wear, corrosion, electrical parameter change, and so on.
- Durability is usually expressed as a minimum time before the occurrence of wearout failures.
- In repairable systems it often characterizes the ability of the product to function after repairs.